What is claimed is:

1. A circuit comprising:

a superconducting qubit having a qubit frequency between 0.8 GHz and 40 GHz;

a resonant control system that is characterized by a resonant frequency, wherein said resonant frequency is a function of a bias current; and

a superconducting mechanism coherently coupled to the superconducting qubit and said resonant control system, wherein said superconducting mechanism has a capacitance or an inductance.

2. The circuit of claim 1, wherein the superconducting qubit is a charge qubit and said superconducting mechanism is a capacitor.

3. The circuit of claim 1, wherein said resonant control system is an anharmonic resonator.

4. The circuit of claim 1, wherein the resonant control system comprises a Josephson junction and a bias current source that is connected in series with the Josephson junction.

5. The circuit of claim 4, wherein said bias current source is $0.994*I_c$ or less, wherein $I_c$ is the critical current of said Josephson junction.

6. The circuit of claim 4, wherein said bias current source is $0.990*I_c$ or less, wherein $I_c$ is the critical current of said Josephson junction.

7. The circuit of claim 1, wherein the resonant control system is superconducting.

8. The circuit of claim 1, the circuit further comprising:

a readout mechanism for reading the quantum state of said superconducting qubit, wherein said readout mechanism is in electrical communication with said superconducting qubit.

9. The circuit of claim 8, wherein said readout mechanism comprises a Josephson junction, a current source, a ground, and a voltmeter connected in parallel.

10. The circuit of claim 1, wherein said superconducting qubit is characterized by a native interaction Hamiltonian that includes an all off diagonal interaction term.

11. The circuit of claim 1, wherein said superconducting qubit is a Josephson junction qubit.

12. The circuit of claim 1, wherein said superconducting qubit is characterized by a native interaction Hamiltonian that includes an all diagonal interaction term.

13. The circuit of claim 12, wherein said superconducting qubit is a charge qubit, a phase qubit, or a flux qubit.

14. A quantum register, comprising:

an array of superconducting qubits;

at least one resonant control system having a characteristic resonance frequency; and

a bus mechanism for capacitively or inductively coupling each superconducting qubit in said array of superconducting qubits to a resonant control system in said at least one resonant control system.

15. The quantum register of claim 14, wherein a resonant control system in said at least one resonant control system comprises a Josephson junction and a bias current source that is in electrical communication with said Josephson junction, and wherein said characteristic resonance frequency is determined by a bias current provided by said bias current source.

16. The quantum register of claim 15, wherein said bias current source is $0.994*I_c$ or less, wherein $I_c$ is the critical current of said Josephson junction.

17. The quantum register of claim 15, wherein said bias current source is $0.990*I_c$ or less, wherein $I_c$ is the critical current of said Josephson junction.

18. The quantum register of claim 14, wherein a resonant control system in said at least one resonant control system is an anharmonic resonator.

19. The quantum register of claim 14, wherein said bus mechanism comprises a plurality of segments and wherein at least a first segment in said plurality of segments capacitively couples a plurality of qubits in said array of qubits to a resonant control system in said at least one resonant control system.

20. The quantum register of claim 19, wherein said plurality of qubits comprises two qubits in said array of superconducting qubits.

21. The quantum register of claim 19, wherein said plurality of qubits comprises three or more qubits in said array of superconducting qubits.

22. The quantum register of claim 19, wherein said bus mechanism further comprises an inter-segment region between said first segment and a second segment in said plurality of segments, and wherein said inter-segment region comprises:

a first coherent superconducting switch that joins said inter-segment region to said first segment; and

a second coherent superconducting switch that joins said inter-segment region to said second segment.

23. The quantum register of claim 22, wherein said first coherent superconducting switch is a first superconducting single electron transistor (SSET) and said second coherent superconducting switch is a second SSET.

24. The quantum register of claim 22, wherein a superconducting pivot qubit is capacitively coupled with said inter-segment region.

25. The quantum register of claim 14, wherein said bus mechanism comprises a plurality of segments, wherein a segment in said plurality of segments is capacitively coupled to a group of qubits in said array of qubits and wherein said segment is coupled to a resonant control system in said at least one resonant control system.

26. The quantum register of claim 14, wherein said array of superconducting qubits comprises a charge qubit that is capacitively coupled to said bus mechanism.

27. The quantum register of claim 14, wherein the array of superconducting qubits comprises a first qubit and a second qubit and wherein said first qubit is a different type of qubit than said second qubit.

28. The quantum register of claim 14, wherein said array of superconducting qubits comprises a qubit that is described by a native interaction Hamiltonian that includes an off diagonal interaction term.

29. The quantum register of claim 28, wherein said qubit is a superconducting charge qubit.

30. The quantum register of claim 14, wherein said array of superconducting qubits comprises a qubit that is described by a native interaction Hamiltonian that includes a diagonal interaction term.

31. The quantum register of claim 30, wherein said qubit is a charge qubit, a phase qubit, or a flux qubit.

32. A method for entangling a quantum state of a first qubit with a quantum state of a second qubit, the method comprising:

tuning a resonant control system, which is capacitively or inductively coupled to said first qubit and said second qubit, to a first frequency for a first period of time, wherein said first frequency corresponds to an energy differential between a first potential energy level and a second potential energy level of said first qubit; and

adjusting said resonant control system to a second frequency for a second period of time, wherein said second frequency corresponds to an energy differential between a first potential energy level and a second potential energy level of said second qubit, thereby entangling the quantum state of the first qubit with the quantum state of the second qubit.

33. The method of claim 32, wherein said resonant control system is an anharmonic resonator.

34. The method of claim 32, wherein said resonant control system is superconducting.

35. The method of claim 32, wherein said resonant control system comprises a Josephson junction and a bias current source that is connected in series with the Josephson junction, and wherein said tuning and adjusting comprise altering a magnitude of said bias current source.

36. The method of claim 35, wherein said bias current source is 0.994*$I_c$ or less during said tuning and adjusting, wherein $I_c$ is the critical current of said Josephson junction.

37. The method of claim 35, wherein said bias current source is 0.990*$I_c$ or less during said tuning and adjusting, wherein $I_c$ is the critical current of said Josephson junction.

38. The method of claim 32, wherein said first period of time is one microsecond or less.

39. The method of claim 32, wherein said first period of time is one hundred nanosconds or less.

40. The method of claim 32, wherein said first qubit is a different type of qubit than said second qubit.

41. The method of claim 32, wherein a length of said first period of time is a function of a length of said second period of time.

42. The method of claim 32, wherein said first period of time is long enough for said resonant control system to entangle with a quantum state of said first qubit.

43. The method of claim 32, wherein said second period of time is one microsecond or less.

44. The method of claim 32, wherein said second period of time is one hundred nanosconds or less.

45. The method of claim 32, wherein a length of said second period of time is a function of a length of said first period of time.

46. The method of claim 32, wherein a length of said second period of time is a length of time that is sufficient for the resonant control system to entangle with the quantum state of said second qubit.

47. The method of claim 32, the method further comprising

applying a first quantum gate to said first qubit prior to said tuning; and

applying a second quantum gate to said first qubit after said tuning.

48. The method of claim 47 wherein said first quantum gate is a Hadamard gate and said second quantum gate is a Hadamard gate.

49. The method of claim 32, the method further comprising:

applying a first quantum gate to said second qubit prior to said adjusting; and

applying a second quantum gate to said second qubit after said adjusting.

50. The method of claim 49 wherein said first quantum gate is a Hadamard gate and said second quantum gate is a Hadamard gate.

51. The method of claim 32, wherein said first qubit, said second qubit, or both said first qubit and second qubit are described by a native interaction Hamiltonian that includes an off diagonal interaction term.

52. The method of claim 51, wherein said first qubit, said second qubit, or both said first qubit and said second qubit are a superconducting charge qubit.

53. The method of claim 32, wherein said first qubit, said second qubit, or both said first qubit and said second qubit are described by a native interaction Hamiltonian that includes a diagonal interaction term.

54. The method of claim 53, wherein said first qubit, said second qubit, or both said first qubit and said second qubit is a charge qubit, a phase qubit, or a flux qubit.

55. A method for entangling a first qubit in a first qubit group with a second qubit in a second qubit group, the method comprising:

(A) coupling, for a first period of time, said first qubit with a first resonant control system by biasing said first resonant control system to a first frequency, said first frequency determined by an energy differential between a first potential energy level and a second potential energy level of said first qubit;

(B) coupling, for a second period of time, said first resonant control system to a pivot qubit by biasing said resonant control system to a second frequency, said second frequency determined by an energy differential between a first potential energy level and a second potential energy level of said pivot qubit;

(C) isolating said pivot qubit from said first qubit group and said first resonant control system;

(D) coupling, for a third period of time, a second resonant control system with said pivot qubit by biasing said second resonant control system to a third frequency, said third frequency determined by said energy differential between said first potential energy level and said second potential energy level of said pivot qubit; wherein said second resonant control system is capacitively or inductively coupled to said second qubit in said second qubit group;

(E) isolating said second qubit group and said second resonant control system from said pivot qubit; and

(F) coupling, for a fourth period of time, said second resonant control system with said second qubit by biasing said second resonant control system to a fourth frequency,

said fourth frequency determined by a first potential energy level and a second potential energy level of said second qubit.

56. The method of claim 55, wherein said first resonant control system is an anharmonic resonator and said second resonant control system is an anharmonic resonator.

57. The method of claim 55, wherein said first resonant control system is superconducting and said second resonant control system is superconducting.

58. The method of claim 55, wherein said first resonant control system includes a Josephson junction and a bias current source, wherein the bias current source is connected in series with the Josephson junction, and wherein said biasing in said coupling (A) and said coupling (B) comprises adjusting said bias current source.

59. The method of claim 55, wherein said bias current source is $0.994*I_c$ or less during coupling (A) and said coupling (B), and wherein $I_c$ is the critical current of said Josephson junction.

60. The method of claim 55, wherein said bias current source is $0.990*I_c$ or less during said coupling (A) and said coupling (B), and wherein $I_c$ is the critical current of said Josephson junction.

61. The method of claim 55, wherein said second resonant control system comprises a Josephson junction and a bias current source, wherein said bias current source is connected in series with the Josephson junction, and wherein said biasing in said coupling (D) and said coupling (F) comprises adjusting said bias current source.

62. The method of claim 61, wherein said bias current source is $0.994*I_c$ or less during said coupling (D) and said coupling (F), and wherein $I_c$ is the critical current of said Josephson junction.

63. The method of claim 61, wherein said bias current source is $0.990*I_c$ or less during said coupling (D) and said coupling (F), and wherein $I_c$ is the critical current of said Josephson junction.

64. The method of claim 55, wherein each of said first period of time, said second period of time, said third period of time, and said fourth period of time is one microsecond or less.

65. The method of claim 55, wherein each of said first period of time, said second period of time, said third period of time, and said fourth period of time is one hundred nanosconds or less.

66. The method of claim 55, wherein said first qubit is a different type of qubit than said second qubit.

67. The method of claim 55, wherein coupling (B) comprises

(i) closing a first switch between said first resonant control system and said pivot qubit for a duration greater than said second period of time; and

(ii) opening said first switch.

68. The method of claim 55, the method further comprising;

(G) coupling said first resonant control system to said first qubit for a period of time equivalent to said first period of time, wherein said coupling is performed after said second period of time has elapsed.

69. The method of claim 55, the method further comprising:

(G) coupling said second resonant control circuit to said first pivot qubit for a period of time that is equivalent to said third period of time, wherein said coupling is performed after said fourth period of time has elapsed.

70. The method of claim 55, the method further comprising:

(G) applying a first quantum gate to said first qubit prior to said coupling (A); and

(H) applying a second quantum gate to said first qubit after said coupling (A).

71. The method of claim 70, wherein said first quantum gate is a Hadamard gate and said second quantum gate is a Hadamard gate.

72. The method of claim 55, the method further comprising:

(G) applying a first quantum gate to said second qubit prior to said coupling (F); and

(H) applying a second quantum gate to said second qubit after said coupling (F).

73. The method of claim 72 wherein said first quantum gate is a Hadamard gate and said second quantum gate is a Hadamard gate.

74. The method of claim 55, wherein said first qubit, said second qubit, or both said first qubit and second qubit are described by a native interaction Hamiltonian that includes an off diagonal interaction term.

75. The method of claim 74, wherein said first qubit, said second qubit, or both said first qubit and said second qubit are a superconducting charge qubit.

76. The method of claim 55, wherein said first qubit, said second qubit, or both said first qubit and said second qubit are described by a native interaction Hamiltonian that includes a diagonal interaction term.

77. The method of claim 76, wherein said first qubit, said second qubit, or both said first qubit and said second qubit is a charge qubit, a phase qubit, or a flux qubit.

78. A method for entangling a quantum state of a first qubit with a quantum state of a second qubit, the method comprising:

(A) tuning a ground state energy difference between a potential energy state of said first qubit and a potential energy state of said second qubit so that the energy difference corresponds to a predetermined frequency; and

(B) biasing a resonant control system, which is capacitively coupled to said first qubit and second qubit, to said predetermined frequency for a period of time.

79. The method of claim 78, wherein said resonant control system comprises a Josephson junction and a bias current source that is connected in series with the Josephson junction, and wherein said biasing comprises adjusting said bias current source.

80. The method of claim 79, wherein said bias current source is $0.994*I_c$ or less during said biasing.

81. The method of claim 79, wherein said bias current source is $0.990*I_c$ or less during said biasing.

82. The method of claim 78, the method further comprising:

(C) applying a first quantum gate to said first qubit prior to said tuning (A); and

(D) applying a second quantum gate to said first qubit after said tuning (A).

83. The method of claim 82, wherein said first quantum gate is a Hadamard gate and said second quantum gate is a Hadamard gate.

84. The method of claim 78, the method further comprising:

(C) applying a first quantum gate to said second qubit prior to said biasing (B); and

(D) applying a second quantum gate to said second qubit after said biasing (B).

85. The method of claim 84 wherein said first quantum gate is a Hadamard gate and said second quantum gate is a Hadamard gate.

86. The method of claim 78, wherein said first qubit, said second qubit, or both said first and second qubit are described by a native interaction Hamiltonian that comprises an off diagonal interaction term.

87. The method of claim 86, wherein said first qubit, said second qubit, or both said first qubit and said second qubit are a superconducting charge qubit.

88. The method of claim 78, wherein said first qubit, said second qubit, or both said first qubit and said second qubit are described by a native interaction Hamiltonian that comprises a diagonal interaction term.

89. The method of claim 88, wherein said first qubit, said second qubit, or both said first qubit and said second qubit is a charge qubit, a phase qubit, or a flux qubit.

90. A method for coupling a system comprising a superconducting qubit and a resonant control circuit, wherein an interaction term of a native interaction Hamiltonian that describes an interaction between said superconducting qubit and said resonant control circuit has a diagonal component, the method comprising:

(A) applying a recoupling operation a first time to the superconducting qubit;

(B) tuning, for an amount of time, the resonant control circuit so that a resonant frequency of the superconducting qubit and a resonant frequency of the resonant control circuit match; and

(C) applying the recoupling operation a second time to the superconducting qubit, thereby transforming the interaction term of the Hamiltonian to have only off-diagonal components.

91. The method of claim 90, wherein said applying the recoupling operation (A) and wherein said applying the recoupling operation (C) comprises implementing a Hadamard gate on the superconducting qubit.

92. The method of claim 91, wherein the Hadamard gate comprises the sequence $Z(\pi/2)$-$X(\pi/2)$-$Z(\pi/2)$, wherein $X(\pi/2)$ is a single qubit $\sigma_x$-based operation and $Z(\pi/2)$ is a single qubit $\sigma_z$-based operation, and said $\sigma_x$-based operation and said $\sigma_z$-based operation are each applied over a phase evolution of $\pi/2$.

93. The method of claim 90, wherein said tuning (B) comprises setting a first energy spacing between a first energy level and a second energy level of the resonant control circuit so that the first energy spacing corresponds to a second energy spacing between a first energy level and a second energy level of the superconducting qubit.

94. The method of claim 93, wherein said setting said first energy spacing is effected by changing a bias current associated with said resonant control circuit.

95. The method of claim 90, wherein a plurality of quantum states of the superconducting qubit are respectively entangled with a corresponding plurality of quantum states of the resonant control circuit during said amount of time.

96. The method of claim 90, wherein the resonant control circuit is characterized by an inductance and a capacitance.

97. The method of claim 96, wherein said inductance is tunable.

98. The method of claim 90, wherein the resonant control circuit comprises a current-biased Josephson junction.

99. The method of claim 98, wherein said tuning (B) comprises changing a current bias across the current-biased Josephson junction.

100. The method of claim 99, wherein said tuning (B) comprises changing a current bias across the current-biased Josephson junction by 1 micro-Ampere or less.

101. The method of claim 99, wherein said tuning (B) comprises changing a current bias across the current-biased Josephson junction by 100 nanoAmperes or less.

102. A method for entangling a state of a first qubit and a state of a second qubit in a system comprising (i) said first qubit, (ii) said second qubit, and (iii) a resonant control circuit, wherein said first qubit, said second qubit, and said resonant control circuit are each respectively coupled to a bus and wherein an interaction term of a native interaction Hamiltonian that describes an interaction between at least one of said first qubit and said second qubit with said resonant control circuit has a diagonal component, the method comprising:

(A) applying a recoupling operation to at least one of said first qubit and said second qubit, wherein said recoupling operation transforms said interaction term so that it has only off-diagonal components;

(B) tuning, for a first amount of time, the resonant control circuit so that a resonant frequency of the first qubit and a resonant frequency of the resonant control circuit match;

(C) tuning, for a second amount of time, the resonant control circuit so that a resonant frequency of the second qubit and a resonant frequency of the resonant control circuit match; and

(D) reapplying the recoupling operation to said at least one of said first qubit and said second qubit.

103. The method of claim 102, further comprising;

(E) tuning, for a third amount of time, the resonant control circuit so that a resonant frequency of the first qubit and a resonant frequency of the resonant control circuit match.

104. The method of claim 102, wherein said first qubit is capacitively coupled to the bus and said second qubit is capacitively coupled to the bus.

105. The method of claim 102, wherein the resonant control circuit is in electrical communication with the bus.

106. The method of claim 102, wherein said applying (A) comprises implementing a Hadamard gate on the at least one of said first qubit and said second qubit.

107. The method of claim 106, wherein the Hadamard gate comprises the sequence $Z(\pi/2)$-$X(\pi/2)$-$Z(\pi/2)$, wherein $X(\pi/2)$ is a single qubit $\sigma_x$-based operation and $Z(\pi/2)$ is a single qubit $\sigma_z$-based operation, and each $\sigma_x$-based operation is applied over a phase evolution of $\pi/2$ and the $\sigma_z$-based operation is applied over a phase evolution of $\pi/2$.

108. The method of claim 102, wherein said tuning (B) comprises setting a first energy spacing between a first energy level and a second energy level of the resonant control

circuit so that they are approximately equal to a second energy spacing between a first energy level and a second energy level of the first qubit.

109. The method of claim 108, wherein said setting the first energy spacing comprises changing a bias current associated with the resonant control circuit.

110. The method of claim 102, wherein said tuning (C) comprises setting said first energy spacing so that it is approximately equal to a third energy spacing between a first energy level and a second energy level of the second qubit.

111. The method of claim 110, wherein said setting the first energy spacing comprises changing a bias current associated with the resonant control circuit.

112. The method of claim 102, wherein a plurality of quantum states of the first qubit is respectively entangled with a corresponding plurality of quantum states of the resonant control circuit during said first amount of time.

113. The method of claim 102, wherein a plurality of quantum states of the second qubit is respectively entangled with a corresponding plurality of quantum states of the resonant control circuit during said second amount of time.

114. The method of claim 102, wherein the resonant control circuit is characterized by an inductance and a capacitance.

115. The method of claim 114, wherein the inductance is tunable.

116. The method of claim 102, wherein the resonant control circuit comprises a current-biased Josephson junction.

117. The method of claim 116, wherein said tuning (B) and said tuning (C) comprises changing a current bias across the current-biased Josephson junction.

118. The method of claim 116, wherein said tuning (B) and said tuning (C) comprises changing a current bias across the current-biased Josephson junction by 1 micro-Ampere or less.

119. The method of claim 116, wherein said tuning (B) and said tuning (C) comprises changing a current bias across the current-biased Josephson junction by 100 nanoAmperes or less.

120. The method of claim 102, wherein said first qubit is superconducting.

121. The method of claim 102, wherein said second qubit is superconducting.

122. The method of claim 102, wherein said resonant control circuit is superconducting.